SEISMIC HAZARD EVALUATION OF THE VENICE 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1998

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

DIVISION OF MINES AND GEOLOGY
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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

> BPS Reprographic Services
> 149 Second Street
> San Francisco, California 94105
> (415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use

by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

DIVISION OF MINES AND GEOLOGY OFFICES

Geologic Information and Publications Office
801 K Street, MS 14-33
Sacramento, CA 95814-3532
(916) 445-5716

Bay Area Regional Office
185 Berry Street, Suite 210
San Francisco, CA 94107-1728
(415) 904-7707

Southern California Regional Office
655 S. Hope Street, Suite 700
Los Angeles, CA 90017
(213) 239-0878

WORLD WIDE WEB ADDRESS

Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Venice 7.5-Minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Venice
7.5-Minute Quadrangle,
Los Angeles County, California

By
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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Venice 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Venice Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

Although the Venice Quadrangle covers an area of about 62 square miles, it includes only about 34 square miles of land east of Santa Monica Bay in southwestern Los Angeles County. Located along the coast, from north to south, are Venice, which is part of Los Angeles, Marina Del Rey (Los Angeles County land), Playa del Rey, the Los Angeles International Airport, the City of El Segundo, and the City of Manhattan Beach. Inland, on the north are parts of the city of Culver City and the community of Westchester (part of Los Angeles). Small slivers of the cities of Inglewood, Hawthorne, and Redondo Beach lie along the eastern boundary of the quadrangle.

The quadrangle includes the shoreline of Santa Monica Bay from Santa Monica south to Hermosa Beach. Venice was developed on the coastal plain south of Santa Monica and includes a series of excavated canals east of the barrier beach. Culver City straddles Ballona Creek and extends up the slopes of the Baldwin Hills. Marina Del Rey was created by Los Angeles County through dredging and modification of the wetlands at the mouth of Ballona Creek in the 1960's. South of Ballona Creek, the land rises abruptly to a broad terrace 100 to 150 feet above sea level. The Westchester area of the City of Los Angeles, the Los Angeles International Airport, and parts of the cities of El Segundo and Manhattan Beach are built on this surface. South of Ballona Creek, hilly topography that consists of ancient sand dunes extends inland about two miles from the coast.

The lowland areas of the Venice Quadrangle are covered with alluvial deposits, mostly of Holocene age. The terrace surface south of Ballona Creek is covered by older alluvial deposits and, locally, with a veneer of Pleistocene dune sand.

GEOLOGIC CONDITIONS

Surface Geology

A digital map obtained from the U.S. Geological Survey (Tinsley, unpublished) was used as a base to prepare a geologic map of the Venice Quadrangle for this project. Additional detail was added from a digital map prepared by the Southern California Areal Mapping Project (SCAMP, unpublished), which was compiled primarily from mapping by Castle (1960a) and Poland and others (1959). Other geologic maps reviewed include Castle (1960b), Weber and others (1982), and CDWR (1961). Geologic contacts were modified using the sources listed above, air photos (Fairchild, 1927), and older topographic maps (USGS, 1934 and USGS, 1930). Stratigraphic nomenclature was revised to follow the format developed by SCAMP (Morton and Kennedy, 1989). The revised geologic map that was used in this study of liquefaction susceptibility is included as Plate 1.1.

The oldest geologic unit mapped in the Venice Quadrangle is the Pleistocene San Pedro Formation (Qsp), a predominantly marine sand and gravel deposit exposed in the Baldwin Hills in the northeast corner of the quadrangle. A resistant, locally pebbly and gravelly, silty sand (Qoa) overlies the San Pedro Formation and caps some of the ridges in this area. A more detailed description of the geology of the Baldwin Hills is presented in Section 2.

Pleistocene older marine (?) sediments (Qom?) forming the southernmost part of the Ocean Park plain extend into the Venice Quadrangle from Santa Monica. These deposits are composed of medium- to coarse-grained sand.

Quaternary sediments exposed on the elevated plain south of Ballona Creek include Pleistocene older alluvium (Qoa) composed of medium- to coarse-grained sand and gravel that interfingers with near-shore marine sediments of similar composition. These deposits are overlain by laterally extensive, stabilized, older eolian deposits (Qoe), which consist of well-sorted, medium- to coarse-grained sand.

Younger alluvium and floodplain deposits (Qya1 and Qya2) are exposed in the low-lying areas of Ballona Gap and Centinela Creek. They generally consist of very fine- to medium-grained sand intermixed with silt and clay.

Prior to the development of Marina Del Rey, extensive estuarine deposits (Qes) were present at the mouth of Ballona Creek. Remnants of these deposits, which consist of organic tidal mud interbedded with floodplain sediments, are mapped around the edges of the marina along with areas of artificial fill (af).

Modern eolian deposits (Qe) form a quarter- to half-mile-wide strip along the coastline adjacent to the modern beach. The eolian deposits are composed of very well-sorted, fine- to medium-grained sand. Modern beach deposits (Qm), which consist of well-sorted, medium- to coarse-grained sand, form the shoreline of Santa Monica Bay.

Subsurface Geology and Geotechnical Characteristics

The geologic units described above were primarily mapped from their surface expression, including interpretation of aerial photos and old topographic maps and soils properties described in soil surveys. The geomorphic mapping was compared with the subsurface properties described in over 180 borehole logs in the study area. Subsurface data used for this study includes the database compiled by John Tinsley for previous liquefaction studies (Tinsley and Fumal, 1985; Tinsley and others, 1985), a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1998), and additional data collected for this study. Subsurface data were collected for this study at Caltrans, DMG files of seismic reports for hospital and school sites, and the Regional Water Quality Control Board. In general, the data gathered for geotechnical studies appear to be complete and consistent. Data from environmental geology reports filed with the Water Quality Control Board are well distributed areally and provide reliable data on water levels. Geotechnical data, particularly SPT blow counts, from environmental

studies are sometimes less reliable however, due to the use of non-standard equipment and incomplete reporting of procedures.

Data from previous databases and additional borehole logs were entered into the DMG Geographic Information System (GIS) database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections from the borehole logs, using the GIS, enabled the correlation of soil types from one borehole to another and the outlining of areas of similar soils.

Descriptions of characteristics of geologic units recorded on the borehole logs are given below. These descriptions are necessarily generalized, but give the most commonly encountered characteristics of the units (see Table 1.1).

Older alluvium (Qoa), older eolian deposits (Qoe), and older marine deposits (Qom?)

Older alluvial and eolian deposits on the Venice Quadrangle cover up the large terrace south of the Ballona Creek channel. This terrace surface consists of older alluvial deposits with a veneer of older, largely stabilized dune sands. Ground water is deep throughout this area, so no extensive effort was made to collect subsurface data. Several logs of deep boreholes from the shear-wave velocity database and the Regional Water Quality Control Board files describe dense to very dense sands and silty sands.

Older marine deposits make up much of the terrace underlying the City of Santa Monica, north of the Venice Quadrangle. A small area of this unit extends onto the northwestern corner of the Venice Quadrangle. They also probably underlie the younger alluvium mapped as Qya1, described below. This material is dense to very dense sand and silty sand.

Younger alluvium (Qya1, Qya2)

Younger alluvium in the lowlands near the mouth of Ballona Creek was subdivided into "alluvium" and "floodplain" deposits by Castle (1960a). For this study these units are called Qya1 and Qya2 to be consistent with SCAMP nomenclature (Morton and Kennedy, 1989). Both of these units have soft clay and silt near the surface but the "alluvium" (Qya1) was described by Castle (1960a) as being a thin veneer over older deposits. This can clearly be seen in the subsurface where the Qya1 deposits are typically ten to 15 feet thick. These deposits consist of silts and clays with some silty sand, overlying dense sand and gravel. The "floodplain" deposits (Qya2) are a much thicker sequence of soft clay, silts and loose to moderately dense sand, commonly with a sand or sandy gravel deposit at 40 to 50 feet depth.

Estuarine deposits (Qes)

Estuarine, or marsh deposits, were mapped by Castle (1960a) in the Marina Del Rey area. These deposits typically include loose to moderately dense silt, sand and clayey sand.

Eolian deposits (Qe)

Eolian Deposits mapped immediately inland from the modern beach are composed of a very thin layer of fine sand, less than 10 feet thick on borehole logs that we were able to obtain. This deposit is typically underlain by dense to very dense sand of the older alluvial deposits.

Beach deposits (Qm)

Modern beach deposits are composed of coarse sand and gravelly sand, up to 23 feet thick on borehole logs we were able to obtain. This deposit is loose to moderately dense. Beach deposits are also typically underlain by dense to very dense sand of the older alluvial deposits.

Artificial fill (af)

Artificial fill on the Venice Quadrangle consists of "engineered" fill in the Marina Del Rey and Ballona Creek areas. Because the engineered fills are too thin to affect the liquefaction hazard, no effort was made to determine their subsurface characteristics.

Geologic Map Unit	Material Type	Consistency	Liquefaction Susceptibility
Qm, beach	Sand, gravelly sand	Loose	high
Qes, estuarine deposit	silty sand, sand	Loose	high
Qya2, younger alluvium	silty sand, sand, clay	loose-moderately dense	high
Qya1, young alluvium	Clay, silt, silty sand (thin)	Soft, loose-moderately dense	Low, locally high
Qoe, older dune sand	silt & silty sand	dense-very dense	low
Qoa, older alluvium	sand & gravel	dense-very dense	low
Qom?, older marine? terrace	sand & gravel	dense-very dense	low

Table 1.1. General geotechnical characteristics and liquefaction susceptibility of younger Quaternary units.

GROUND-WATER CONDITIONS

A ground-water evaluation of alluviated areas was performed in order to determine historically shallow ground-water levels in the Venice Quadrangle. Areas characterized by historical groundwater or perched water with depths of less than 40 feet are considered for the purposes of liquefaction hazard zoning. The evaluation relied heavily on turn-of-the-century water-well logs (Mendenhall, 1905) but also included water measurements from borehole logs collected for this study. The depths to first encountered water free of piezometric influences were plotted and contoured onto a map showing depths to historically shallowest ground water (Plate 1.2). This map was digitized and used for the liquefaction analysis. The map was compared to similar published maps for any discrepancies (Tinsley and others, 1985; Leighton and others, 1990).

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to evaluate liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of

exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Venice Quadrangle, peak accelerations of 0.44 g to 0.60 g resulting from earthquakes of magnitude 6.6 to 7.3 were used for liquefaction analyses. The PGA and magnitude values were derived from maps prepared by Petersen and others (1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense. Cohesive soils are generally not considered susceptible to liquefaction.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. A qualitative susceptible soil inventory is outlined below and summarized in Table 1.1.

Older alluvium (Qoa), older eolian deposits (Qoe), and older marine deposits (Qom?)

Older alluvial, eolian, and marine deposits are composed of dense to very dense sands and silty sands. Liquefaction susceptibility of these units is low.

Younger alluvium (Qya1, Qya2)

Young alluvium in the lowlands near the mouth of Ballona Creek was subdivided into "alluvium" and "floodplain" deposits by Castle (1960a). Qya1 is a thin deposit of silt and clay with some local layers of silty sand. Liquefaction susceptibility of the silty sand layers is high. Much of this unit is less than 10 feet thick, overlying dense older deposits. Where Qya1 is unsaturated because ground water is deeper than the thickness of the unit, liquefaction susceptibility is low. Qya2 consists of silt, clay and silty sand, which is loose to moderately dense and, commonly, saturated. Liquefaction susceptibility of this unit is high.

Estuarine deposits (Qes)

Estuarine deposits include loose to moderately dense silt, sand and clayey sand. In an area with a very shallow water table. Liquefaction susceptibility of this unit is high.

Eolian deposits (Qe)

Eolian deposits are composed of a very thin layer of fine sand, less than 10 feet thick. Because it is so thin, it is above the historically highest water table. This deposit is typically underlain by dense to very dense sand of older alluvial deposits. Liquefaction susceptibility of this unit is low.

Beach deposits (Qm)

Beach deposits include loose sand and gravelly sand. Liquefaction susceptibility of this unit is high.

Artificial fill (af)

Artificial fills commonly overlie young alluvial or estuarine deposits. Because the engineered fills are usually too thin to affect the liquefaction hazard, and the underlying estuarine deposits have a high liquefaction susceptibility, they are assumed to have a high susceptibility to liquefaction.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses, expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. Generally, a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, indicates the presence of potentially liquefiable soil. DMG uses FS, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Of the 183 borehole logs compiled for this study, 133 include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc.) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values, or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient**.**

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Venice Quadrangle is summarized below.

Areas of Past Liquefaction

In the Venice Quadrangle, minor effects attributed to liquefaction were noted in Marina Del Rey following the 1994 Northridge earthquake, especially a modest concentration of pipe breakage between Washington Boulevard and Culver Boulevard (Stewart and others, 1994, p.129 and Figure 4.75). In addition, a sand fissure was reported by the Los Angeles County, Department of

Harbors and Beaches (see Plate 1.2) in an artificial beach area at the marina near the intersection of Via Marina and Admiralty Way (Stewart and others, 1994).

In his discussion of the effects of the June 21, 1920, Inglewood earthquake, Taber described and pictured (1920, p. 140 and Plate 14, figure 2) a "low ridge about one and one half feet high and fifteen feet broad" that crossed the furrows in a farm field in the Centinela Creek Valley near the eastern boundary of the Venice 7.5-minute Quadrangle. He also described a depression that had developed between the ridge and another, parallel one about one hundred yards to the northeast. This feature is suggestive of differential settlement and may have been related to liquefaction in the creek valley sediments.

Artificial Fills

In the Venice Quadrangle artificial fill consists of engineered fill around the Marina Del Rey area. The engineered fills are generally too thin to have an impact on liquefaction but overlie estuarine deposits that are susceptible to liquefaction. Areas underlain by artificial fill have been included in liquefaction hazard zones.

Areas with Existing Geotechnical Data

The older alluvium, marine deposits, and eolian deposits exposed in the Venice Quadrangle (Qoa, Qoe, and Qom?) have a dense consistency and deep ground water was encountered in boreholes in much of the area underlain by these units. Accordingly, these geologic units have not been included in a liquefaction hazard zone.

Younger eolian deposits are typically very thin, and, therefore, unsaturated. They are not included in liquefaction hazard zones.

Younger alluvial deposits (Qya1 and Qya2) commonly have layers of loose silty sand or sand. Where these deposits are saturated, they are included in a liquefaction hazard zone. The thickness of Qya1 is typically less than 10 feet, therefore areas underlain by Qya1 where the water table is at greater than 10 feet are not included in the liquefaction hazard zone.

Modern beach deposits are typically loose saturated sand. They are included in liquefaction hazard zones.

ACKNOWLEDGMENTS

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT
Earthquake-Induced Landslide Zones in the Venice 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Venice 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Typically, areas most susceptible to earthquake-induced landslides are on steep slopes and on or adjacent to existing landslide deposits, especially if the earth materials in these areas are composed of loose colluvial soils, or poorly cemented or highly fractured rock. These geologic and terrain conditions exist in many parts of southern California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Venice Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Venice Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

Although the Venice Quadrangle covers an area of about 62 square miles, it includes only about 34 square miles of land east of Santa Monica Bay in southwestern Los Angeles County. Located along the coast, from north to south, are Venice, which is part of Los Angeles, Marina Del Rey (Los Angeles County land), Playa del Rey, the Los Angeles International Airport, the City of El Segundo, and the City of Manhattan Beach. Inland, on the north are parts of the city of Culver City and the community of Westchester (part of Los Angeles). Small slivers of the cities of Inglewood, Hawthorne, and Redondo Beach lie along the eastern boundary of the quadrangle.

The quadrangle includes the shoreline of Santa Monica Bay from Santa Monica south to Hermosa Beach. Venice was developed on the coastal plain south of Santa Monica and includes a series of excavated canals east of the barrier beach. Culver City straddles Ballona Creek and extends up the slopes of the Baldwin Hills. Marina Del Rey was created by Los Angeles County through dredging and modification of the wetlands at the mouth of Ballona Creek in the 1960's. South of Ballona Creek, the land rises abruptly to a broad terrace 100 to 150 feet above sea level. The Westchester area of the City of Los Angeles, the Los Angeles International Airport, and parts of the cities of El Segundo and Manhattan Beach are built on this surface. South of Ballona Creek, hilly topography that consists of ancient sand dunes extends inland about two miles from the coast.

The lowland areas of the Venice Quadrangle are covered with alluvial deposits, mostly of Holocene age. The terrace surface south of Ballona Creek is covered by older alluvial deposits and, locally, with a veneer of Pleistocene dune sand.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

A digital map obtained from the U.S. Geological Survey (Tinsley, unpublished) was used as a base to prepare a geologic map of the Venice Quadrangle for this project. Additional detail was added from a digital map prepared by the Southern California Areal Mapping Project (SCAMP, unpublished), which was compiled primarily from mapping by Castle (1960a) and Poland and others (1959). Other geologic maps reviewed include Castle (1960b), Weber and others (1982), and CDWR (1961). Geologic contacts were modified using the sources listed above, air photos (Fairchild, 1927), and older topographic maps (USGS, 1934 and USGS, 1930). In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

Bedrock exposures in the Venice Quadrangle are limited to the northeast corner of the map where strata have been uplifted, folded, and faulted along the Newport-Inglewood structural zone to form the Baldwin Hills. The Baldwin Hills are primarily composed of marine sediments of Pleistocene age. Stratigraphic correlation of Plio-Pleistocene and Quaternary strata within the Los Angeles Basin is difficult because of rapid lateral facies changes resulting from fluctuations in the paleo-shoreline and the time-transgressive nature of the faunal assemblages (Quinn and others, 1997). Because of the current lack of well-defined Quaternary correlations and nomenclature, the formation designations used in this study for the Baldwin Hills area should be regarded as generalized and informal.

The oldest geologic unit mapped in the Venice Quadrangle is the Pleistocene San Pedro Formation (Qsp; "B" formation of Castle, 1960a and 1960b), which is exposed in the Baldwin Hills in the northeast corner of the quadrangle. The San Pedro Formation consists of poorly consolidated, fine- to coarse-grained sand interbedded with thin beds and lenses of gravel deposited in a near-shore marine environment ("Qc" in Weber and others, 1982). Also included in this unit are fluvial sand and gravel with local beds of clayey silt ("Qb" in Weber and others, 1982). A reddish brown, well-cemented and resistant, locally pebbly or gravelly, silty sand caps some of the ridges in the Baldwin Hills and is designated older alluvium (Qoa; "Qf" in Weber and others, 1982; "cap deposits" in Castle, 1960a and 1960b).

Quaternary sediments that cover the remainder of the Venice Quadrangle include older marine deposits (Qom) extending into the northwest corner from Santa Monica, older alluvium (Qoa) and older eolian deposits (Qoe) on the elevated plain south of Ballona Creek, modern eolian deposits (Qe) and beach sand (Qm) fringing the coastline, modern estuarine deposits (Qes) in the Ballona Creek and Marina Del Rey area, and younger alluvial-fan and floodplain deposits (Qya1 and Qya2) in the northern part of the quadrangle on the margins of the Baldwin Hills, and along Ballona Gap and Centinela Creek. Small, surficial landslides (Qls and Qls?) have occurred along the bluffs on the south side of Ballona Creek and on steeper slopes in the Baldwin Hills. Modern man-made (artificial) fills (af) are also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Venice Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they must first be ranked on the basis of their overall shear strength. The primary source for rock shear-strength measurements is geotechnical reports prepared by consultants, on file with local government permitting departments. Shear strength data for the rock units identified on the geologic map were obtained from the City of Los Angeles, Department of Building and Safety and from CDMG documents (see Appendix A). The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above sources were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average $\mathbf{f}$) and lithologic character. When available, shear tests from adjacent quadrangles were used to augment data for

geologic formations that had little or no shear test information. For the Venice Quadrangle, shear test values used to characterize rock strength were borrowed from adjacent quadrangles. Shear tests for Qya were obtained from the Inglewood Quadrangle and additional values for Qsp were obtained from the Hollywood Quadrangle. No shear tests were available for af, Qm, Qom?, Qes, and Qya1. These geologic units were added to existing groups on the basis of lithologic and stratigraphic similarities.

The results of the grouping of geologic materials in the Venice Quadrangle are in Tables 2.1 and 2.2.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Venice Quadrangle was prepared (Irvine, unpublished) by using previous work done in the area (Weber and others, 1979; Weber and others, 1982) and by combining field observations, analysis of aerial photos, and interpretation of landforms on current and older topographic maps. The following aerial photos were used for landslide interpretation: Fairchild (1927) and USGS (1994a; 1994b). The completed hand-drawn landslide map was scanned, digitized, and the database was attributed with information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). A version of this landslide inventory is included with Plate 2.1.

	Formation Name	Number of Tests	Mean/Median Phi	Mean/Median (Group Phi) (deg)	Group Mean/Median C (psf)	No Data: Similar Geologic Strength	Phi Values Used in Stability Analysis
VENICE QUADRANGLE SHEAR STRENGTH GROUPINGS							
GROUP 1	Qoe	54	31.1/31	30.2/31	251/215	Af	30.2
	Qoa	41	29.8/31			Qom?	
	Qe?	3	29/27			Qes	
	Qsp	30	28.2/30				
	Qe	1	27/27				
GROUP 2	Qya	3	26.3/26	26.3/26	300/300	Qya1	26
GROUP 3	Qls	-	-	-	-	-	15

Table 2.1.   Summary of the shear strength statistics for the Venice Quadrangle.

SHEAR STRENGTH GROUPS FOR THE VENICE QUADRANGLE		
GROUP 1	**GROUP 2**	**GROUP 3**
af Qe Qes Qs? Qm Qoa Qoe Qom? Qsp	Qya1 Qya2	Qls

Table 2.2.   Summary of the shear strength groups for the Venice Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Venice Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.9 to 7.1
Modal Distance:	2.5 to7.4 km
PGA:	0.40 to 0.49 g

The strong-motion record selected was the Channel 3 (north horizontal component) University of Southern California Station #14 recording from the magnitude 6.7 Northridge earthquake (Trifunac and others, 1994). This record had a source to recording site distance of 8.5 km and a PGA of 0.69 g. The selected strong-motion record was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129
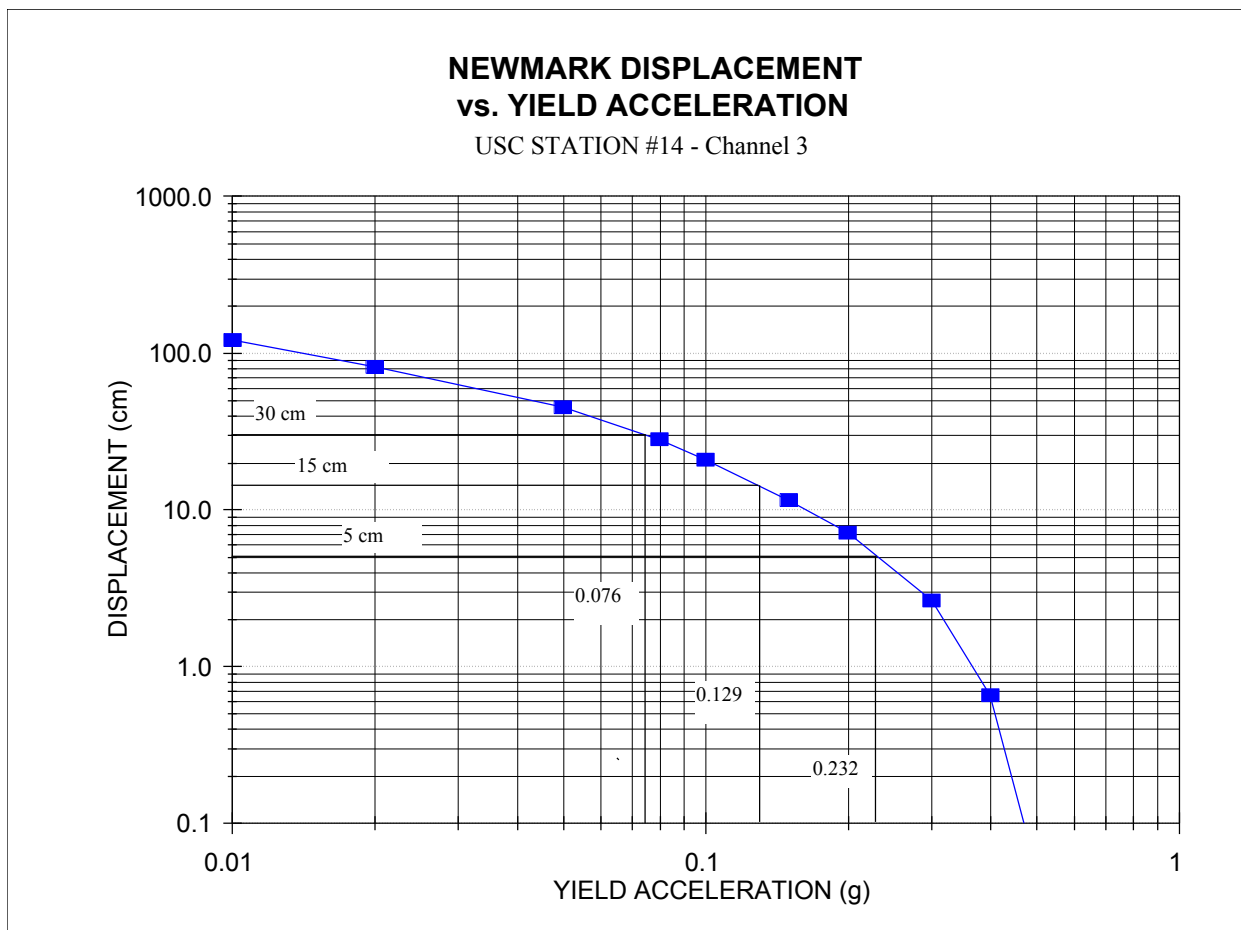
Figure 2.1. Yield acceleration vs. Newmark displacement for the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

and 0.232 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Venice Quadrangle.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Venice Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. A program that adds a pixel to the edges of the DEM was run twice to avoid the loss of data at the quadrangle edges when the slope calculations were performed. A peak and pit smoothing process was then performed to remove errors in the elevation points.

A slope-gradient map were made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The slope-gradient map was used with the geologic strength map in preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equations represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076g, expected displacements could be greater than 30cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129g a MODERATE (M on Table 2.3) hazard potential was assigned, between 0.129 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

VENICE QUADRANGLE HAZARD POTENTIAL MATRIX											
		SLOPE CATEGORY (% SLOPE)									
Geologic Material Group	Mean Phi	I 0-14	II 14-19	III 19-27	IV 27-34	V 34-36	VI 36-42	VII 42-45	VIII 45-50	IX >50	Percent
1	30	VL	VL	VL	VL	L	L	L	M	H	
2	26	VL	VL	VL	L	L	M	H	H	H	
3	15	L	M	H	H	H	H	H	H	H	

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Venice Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (in press). Under those criteria, earthquake-induced landslide zones are areas meeting one or more of the following:

1. Areas known to have experienced earthquake-induced slope failure during historic earthquakes.

2. Areas identified as having past landslide movement, including both landslide deposits and source areas.

3. Areas where CDMG's analyses of geologic and geotechnical data indicate that the geologic materials are susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 3 is always included in the zone (mapped landslides): strength group 2 materials are included in the zone for all slope gradients above 27%; and strength group 1 materials, the strongest rock types, are zoned for slope gradients above 34%. This results in roughly 1% of the land in the quadrangle lying within the hazard zone.

ACKNOWLEDGMENTS

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APPENDIX A
SOURCES OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
City of Los Angeles, Department of Building and Safety	**105**
CDMG Special Report 152	**19**
CDMG Hospital Site Reviews	**3**
Total number of tests used to characterize the units in the Venice Quadrangle	**127**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the
Venice 7.5-Minute Quadrangle,
Los Angeles County, California

By

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Charles R. Real and Michael S. Reichle

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Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions *for the analysis of ground failure* according to the "Simple

Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998
FIRM ROCK CONDITIONS
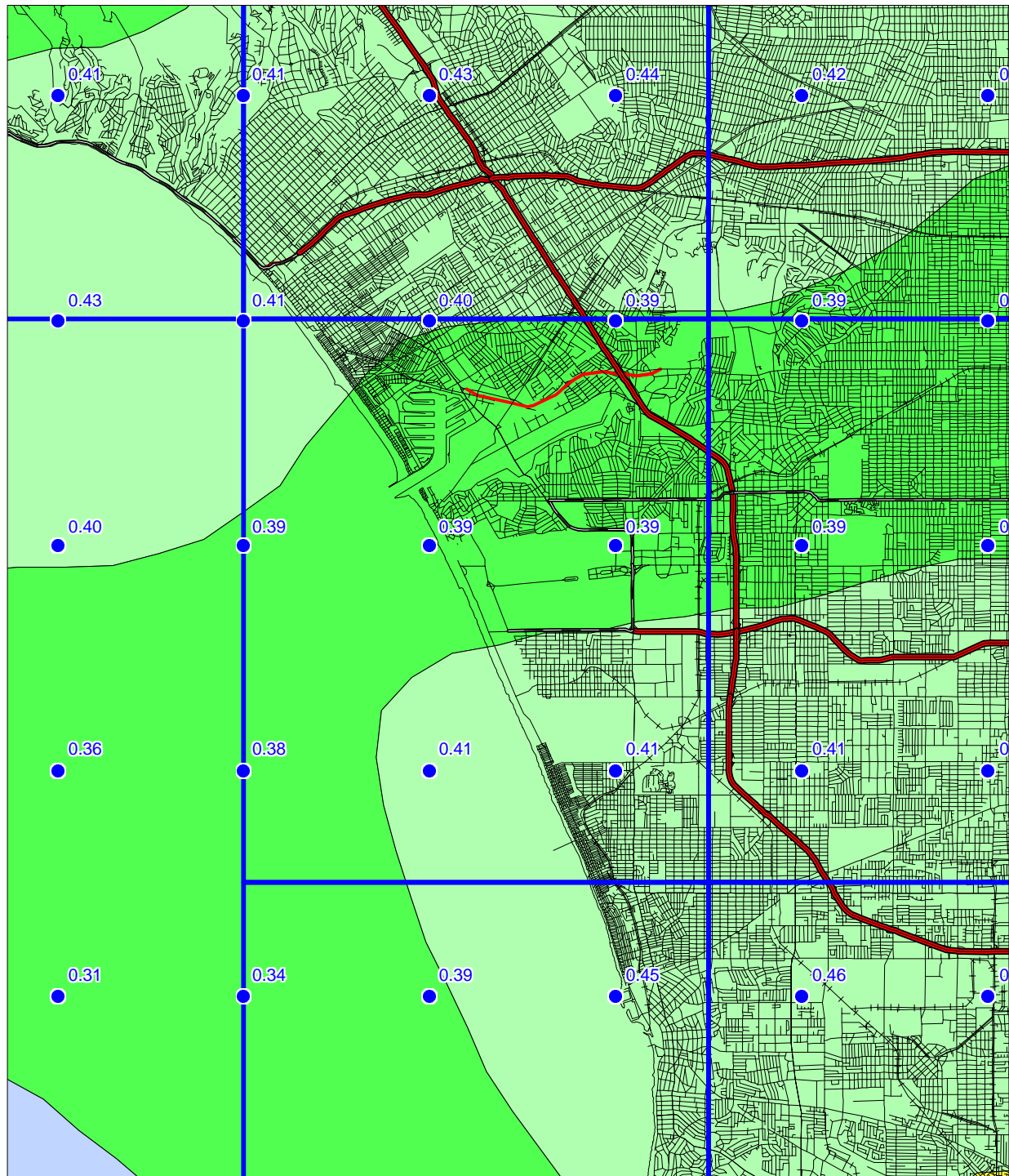
Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0   2.5   5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.1

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS

Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0   2.5   5
Kilometers

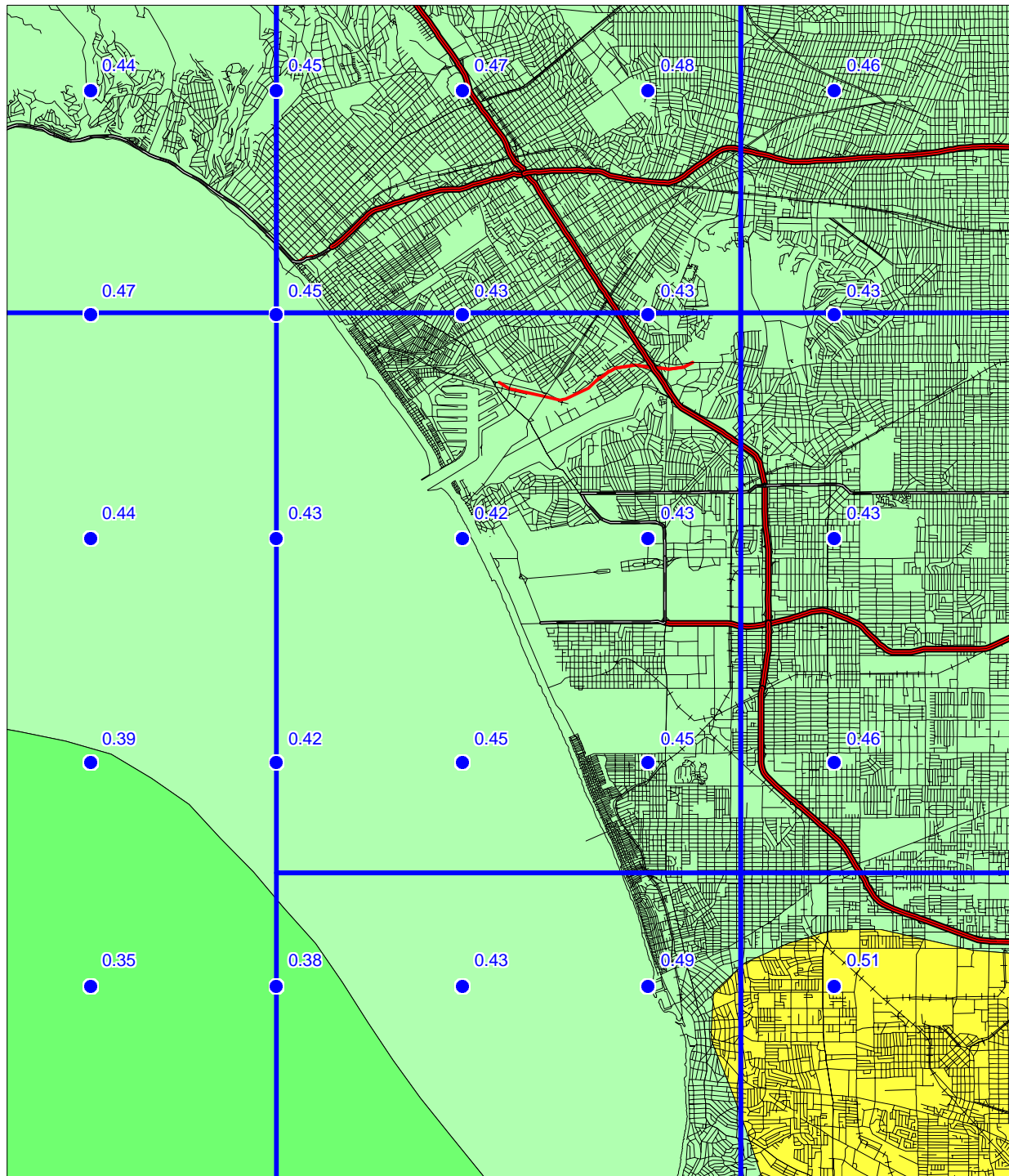Department of Conservation
Division of Mines and Geology

Figure 3.2

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS

Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0   2.5   5

Kilometers

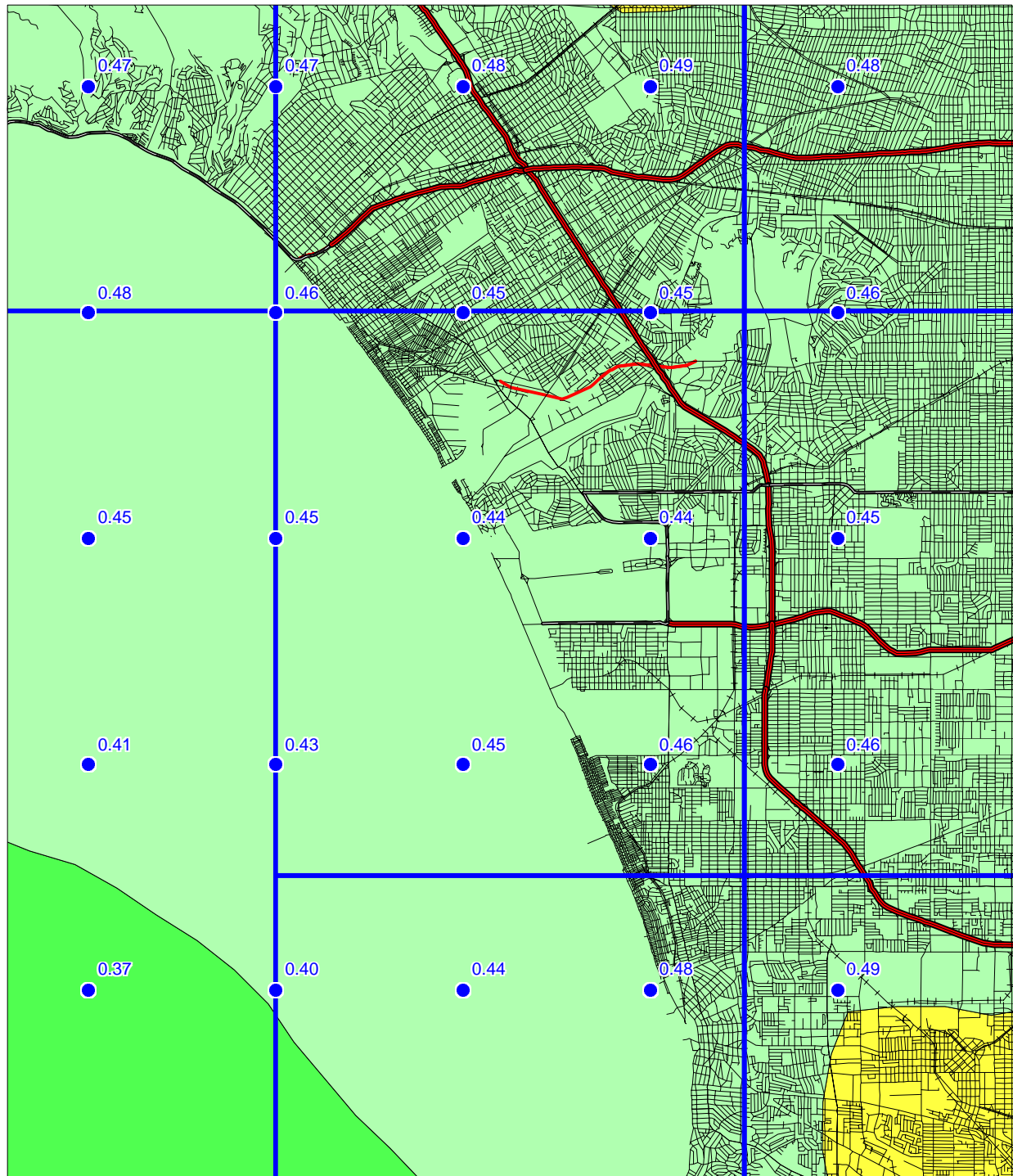Department of Conservation
Division of Mines and Geology

Figure 3.3

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a

VENICE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION
1998
PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))

Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

Department of Conservation
Division of Mines and Geology
Figure 3.4

0   2.5   5
Kilometers

single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours.*

1. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

2. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

3. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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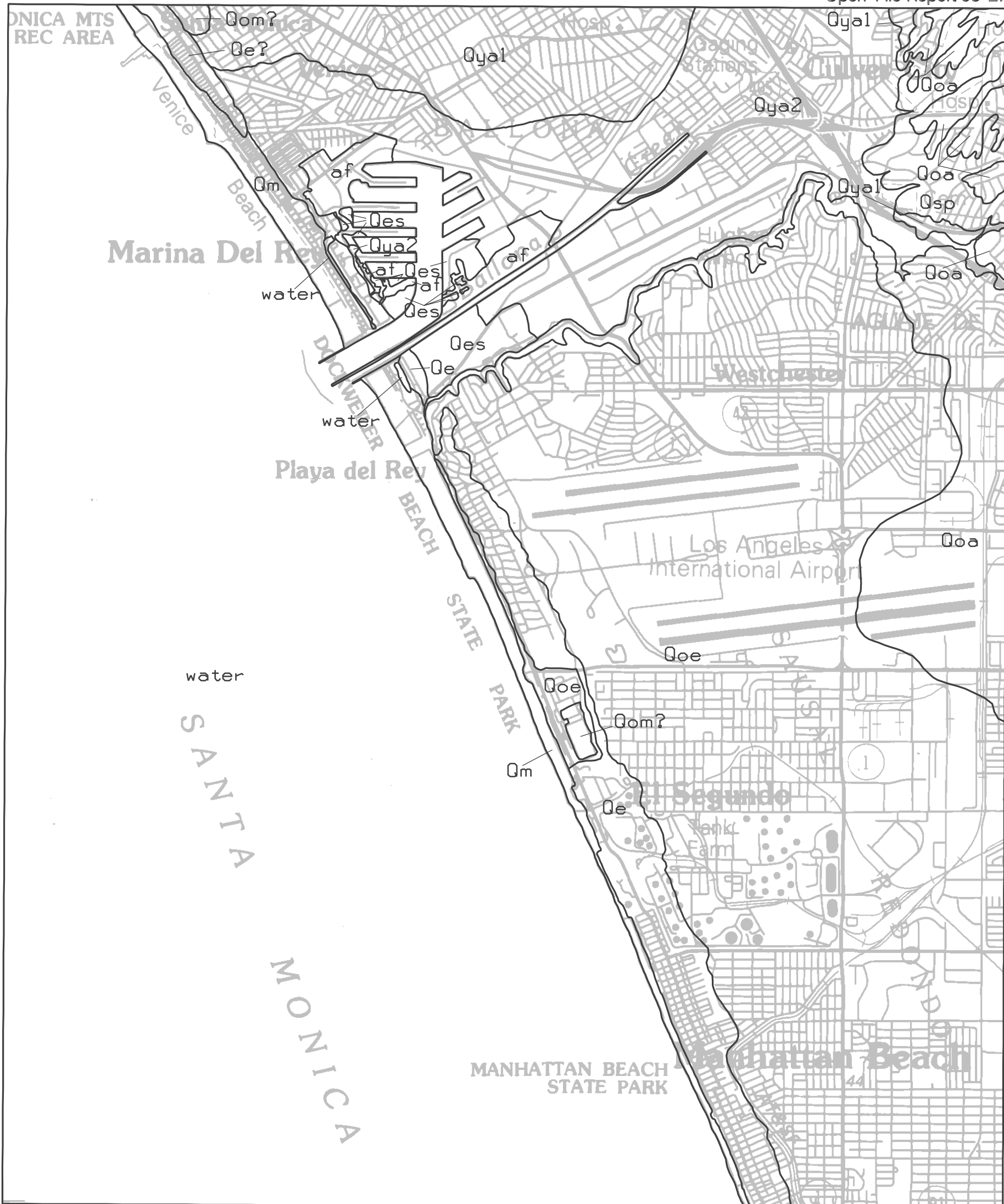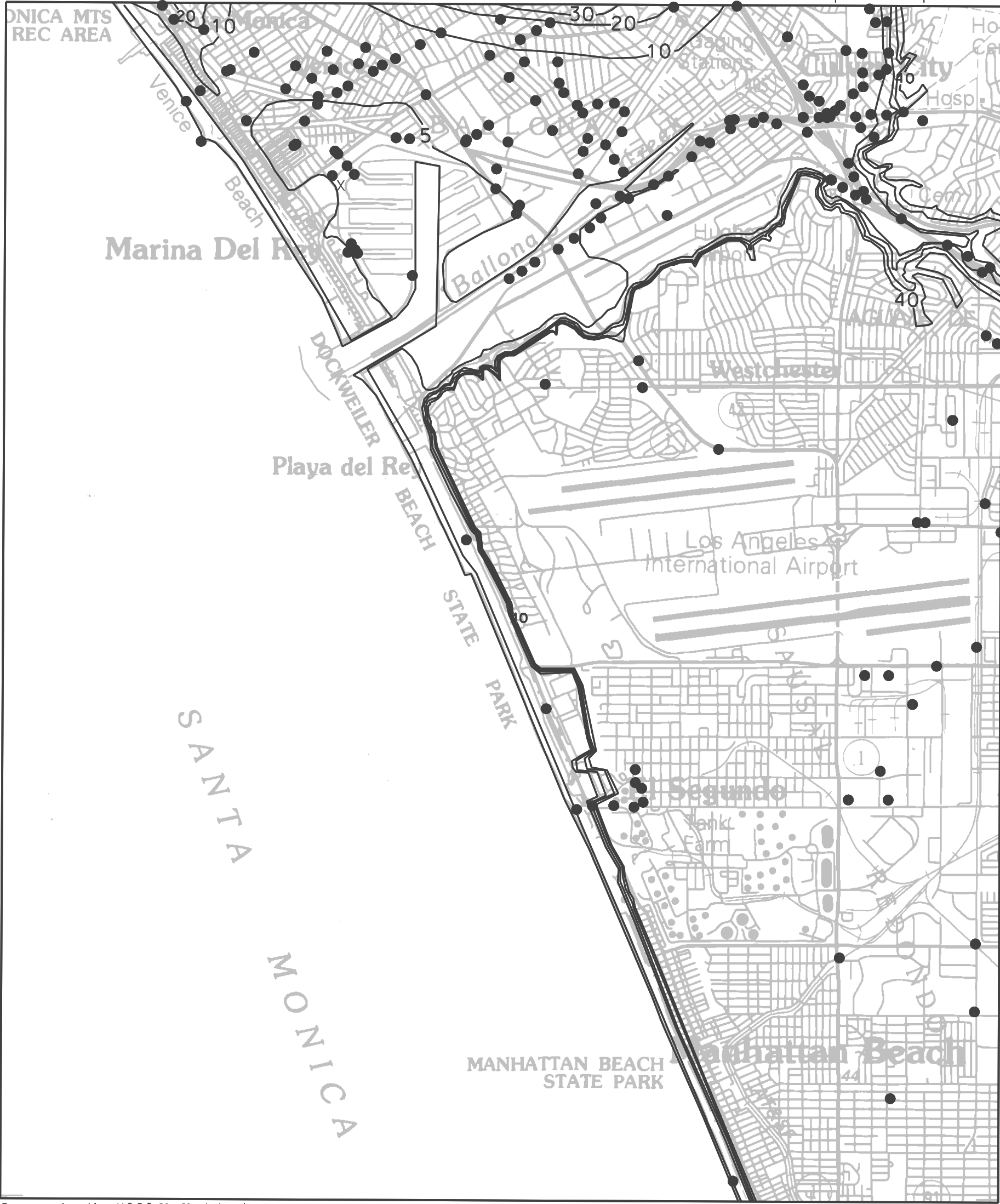
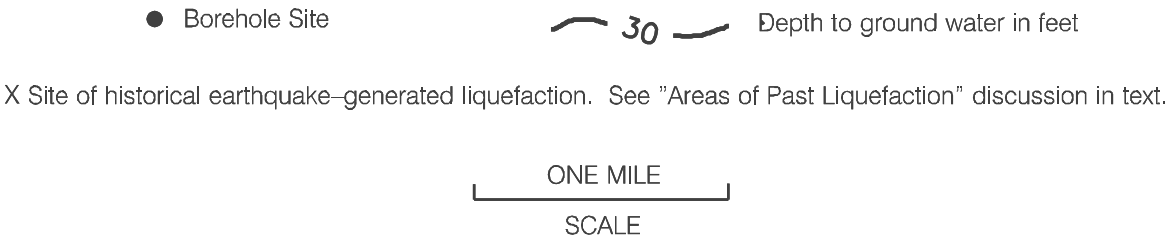Plate 1.1 Quaternary Geologic Map of the Venice Quadrangle.

See Geologic Conditions section in report for descriptions of the units.

ONE MILE

SCALE

Base map enlarged from U.S.G.S. 30 x 60–minute series
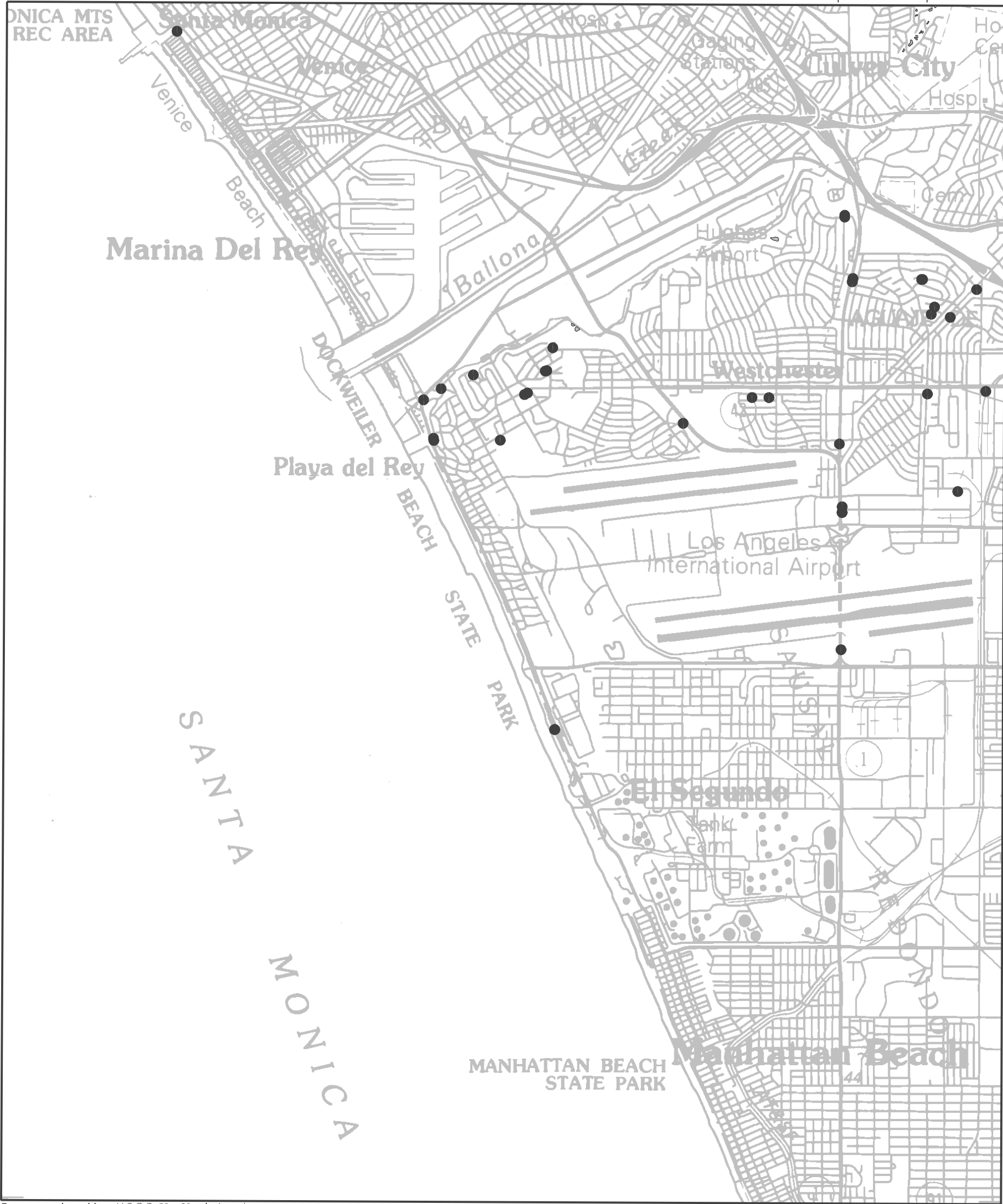
Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Venice Quadrangle.

● Borehole Site   ⌒ 30 ⌒ Depth to ground water in feet

X Site of historical earthquake–generated liquefaction. See "Areas of Past Liquefaction" discussion in text.

ONE MILE

SCALE

Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, Venice Quadrangle.

● shear test sample location   ⬭ landslide

ONE MILE

SCALE